Astronomy

LEARNING OUTCOMES

After completing this chapter, you should be able to:
- Identify some of the latest space discoveries.
- Discuss any new planetary discoveries.
- Discuss latest findings con cerning stars.

Astronomers have been studying the stars for hundreds of years, and yet the fascination remains with us today. We are fascinated by the unknown, by what might be, and by the sheer beauty and wonder of space.

Many books discuss the planets within our solar system, and the other bodies existing in space. In fact, CAP's Aerospace: The Journey of Flight is a good source for reading and learning about these entities. This chapter is not going to elaborate on this already covered territory. Instead, we want to bring you up to date on the latest scientific discoveries within our universe.

I have collected and compiled several articles from various NASA websites. Sometimes, I printed the article intact, other times I took excerpts from the articles to give you the latest investigations and discoveries in space. These articles are presented chronologically beginning with 1999 - 2003. We hope you enjoy the articles and learn new information about space discoveries.

Jupiter's Composition Throws Planet-formation Theories into Disarray

By Robert Roy Britt, Senior Science Writer

Posted: 12:06 P.M. ET, 17 November 1999

Examining four-year-old data, researchers have found significantly elevated levels of certain elements in Jupiter's atmosphere that may force a rethinking of theories about how the planet, and possibly the entire solar system, formed. The work may even help explain why giant planets have been found curiously close to other stars.

The elements -- argon, krypton and xenon -- are called noble gases. They are independent characters that don't like to be trapped and strongly resist freezing except at the lowest temperatures (scientists say they are inert). Therefore, they are either rare or nonexistent in the sun, on Earth and in asteroids and comets inside the orbit of Neptune, where temperatures are relatively warm compared with the more frozen reaches of space.

So the discovery in Jupiter's atmosphere of relatively large amounts of these gases -- up to three times what exists in the sun -- has scientists puzzling over how, and possibly where, Jupiter trapped the noble gases in the first place. The puzzle will be described, though not solved, in Thursday's issue of the journal Nature.

"The implications are enormous," said Sushil Atreya, director of the Planetary Science Laboratory at the University of Michigan and part of the international team of researchers that made the discovery.

How planets formed … maybe

Prevailing theories of planetary formation hold that the sun gathered itself together in the center of a pancake-shaped disk of gas and dust, then the planets begin to take shape by cleaning up the leftovers. A developing planet trapped nearby gas and dust, and its gravitational tug reigned in comets and other icy bodies, called planetesimals.

In Jupiter's current orbit, 5 astronomical units from the sun, temperatures are too warm for the planetesimals to have trapped the noble gases, researchers say (one astronomical unit, or AU, is the distance from the sun to Earth). Only in the Kuiper belt -- a frigid region of the solar system more than 40 AU from the sun -- could planetesimals have trapped argon, krypton and xenon.

"How did they become so abundant on Jupiter?" asks lead researcher Tobias Owen of the University of Hawaii's Institute for Astronomy.

Owen and his colleagues speculate that either the developing solar nebula was far colder than current models estimate, or else Jupiter wandered into its present orbit sometime after having formed. A third possibility, and the one Owen considers the most likely, is that planetesimals began forming earlier and more rapidly, before the presolar disk had warmed up. Either answer throws current theories into disarray.

And solving the puzzle, Owen says, has implications even beyond our solar system.

"If the planetesimals really formed so early and so fast, then they could build giant planets much closer to their stars than people have thought," Owen explained in an e-mail interview. "This would help to explain why the new planetary systems that are being discovered have giant planets so close to their stars. The planets would not have to migrate inward as far as people have thought."

How the finding was made

In 1995, NASA's Galileo spacecraft dropped a probe into Jupiter's atmosphere. An onboard "mass spectrometer" measured the quantities of various gases. Researchers have been analyzing the data in recent years, but they worked on the most abundant elements first. While that research was valuable, it was the more recent work that proved most surprising.

"The excitement is all about argon, krypton and xenon," Owen said. "You are breathing tiny traces of them right now as you read this."

Owen said the three noble gases are as abundant in the jovian atmosphere as are carbon and sulfur, a "surprising" result. Jupiter's primary ingredients, like that of the sun and the stars, are hydrogen and helium.

Is Jupiter a wanderer?

While Owen does not put much stock in the idea that Jupiter might have migrated inward to its present position, other scientists on the team say the idea merits consideration. As evidence of how little we know about the possibilities, they cited recent announcements of a possible tenth planet orbiting at an incredibly far-out 25,000 AU or more, as well as the fact that planets much larger than Jupiter have been found extremely close to other stars.

But the idea of Jupiter as a wanderer still leaves significant questions about the source of the noble gases. "If Jupiter had migrated inward, it would have had to come from way out there, 40 or 50 astronomical units," said Atreya, the Planetary Science Laboratory director.

Owen said that experts on the physics controlling this kind of migration think such a scenario is "highly unlikely." Researchers add that this distant region of the solar system -- the Kuiper belt at 40 to 50 AU -- does not currently have enough mass to account for something Jupiter-sized, nor are the concentrations of heavy elements comparable to what is found in Jupiter.

"You have to characterize our understanding of how the solar system got started as sort of in a state of flux," said Thomas Donahue, also of the Planetary Science Laboratory. "There may be more to the solar system than we know about."

Where do we go from here?

Since there now seems to be much more learning to do, Owen and his colleagues are calling for more spacecraft to deploy probes into the other gaseous planets. Owen expects the probes will find similarly high levels of noble gases in Saturn, Uranus and Neptune. Hints of these gases have even been found in the thick atmosphere of Venus, another planet now begging more study.

And Owen said answers to the origin of all this argon, krypton and xenon may still be lurking out there, awaiting discovery: "Comets are probably more diverse than we think, and there may still be some of these very primitive objects left in the comet pool."

Three Extrasolar Planets Found By Telescope Down Under

posted: 07:00 am ET
12 December 2000

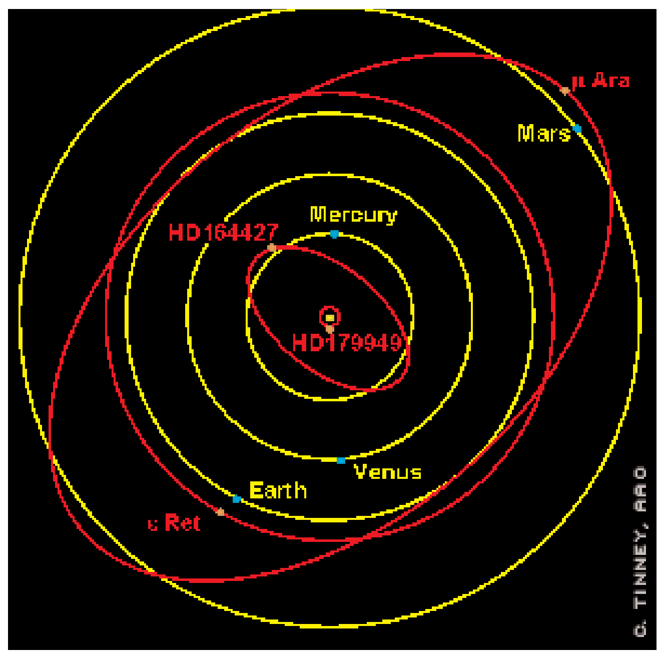
Three planets around distant stars have been found by scientists using a new high-precision system on the Anglo-Australian Telescope (AAT). The new planets were found around nearby stars within 150 light-years of Earth. Forty-six other extrasolar planets have been found since 1995, with the most recent three being the first found by a telescope "down under."

Most planet searches have detected planets more massive than Jupiter, the largest planet in our solar system.

"As a result, searches are picking up all the weird giant planets first," says team leader Chris Tinney of the Anglo-Australian Observatory.

The smallest of the new trio is a kind planet hunters call a "hot Jupiter." It has a mass at least 84 percent that of Jupiter's but lies scorchingly close to its parent star, far closer than Mercury does to the Sun. Its "year," or the time it takes to make a single revolution around its star, is a mere three Earth days.

The middleweight planet lies in an Earth-like orbit inside the "habitable zone" where liquid water could exist. The planet itself is not Earth-like: weighing at least 1.26 Jupiter masses, it is almost certainly a Jupiter-like gas giant. It takes a leisurely 426 days to complete the voyage around



This image compares the orbits of the four new planets -- each discovered around its own star -- with the orbits of our inner solar system planets. Like the planets of our own solar system, epsilon Reticulum and HD179949 have nearly circular orbits. In comparison, the brown dwarf HD164427 and mu Ara lie on very elongated orbits. If mu Ara lay in our own solar system it would swing between the orbits of the Earth and Mars once every year.

its star, epsilon Reticulum in the constellation of the Net.

The third planet is also a gas giant of at least 1.86 Jupiter masses. Its orbit extends just a bit further from its star than Mars does from the Sun. It takes 743 days to crawl around its star, mu Ara, in the constellation of the Altar.

Since 1998 the AAT search has looked at 200 nearby stars in the southern sky. There are probably more planets in the pipeline, says Tinney.

"In three years you can catch only the short-period planets," he said. "To pick up ones with longer orbits you have to observe for a few more years." The AAT searchers also found a single brown dwarf, a small "failed-star star," in orbit around HD164427.

How it's done

The AAT search complements searches of the northern sky being done by veteran planet hunters Geoffrey Marcy, Paul Butler and Michel Mayor.

Both these and the AAT search use the "wobble" technique. As an unseen planet orbits a distant star it tugs on it, causing the star to move back and forth in space. That wobble can be detected by the Doppler shift it causes in the star's light.

"The AAT search is the most sensitive search in the Southern Hemisphere," says team member Alan Penny of Rutherford Appleton Laboratory in the United Kingdom.

The precision comes from simple glass tube containing specks of iodine, and "a bunch of clever software" written by Paul Butler, says Tinney.

Heating the glass cell turns the iodine to a purple gas. Starlight passing through the gas has its spectrum modified. This reference spectrum is then compared with unmodified starlight. "This helps us get much of the junk out of the spectrum," Butler said.

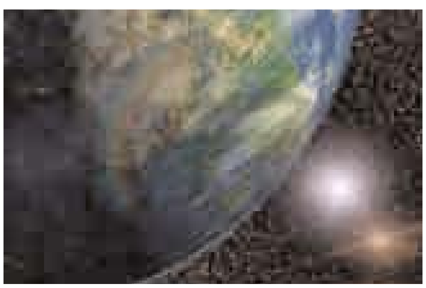
Along with Butler, of the Carnegie Institution of Washington, and Marcy, of UC Berkeley, Tinney worked to find the three planets with researchers from Liverpool John Moores University, Rutherford Appleton Laboratory, University of Sussex, University of Colorado, University of California Santa Cruz and Tennessee State University.

Future searches

Seeing wobbling stars directly is the next step in planet hunting. That job will fall first off to the Very Large Telescope Inteferometer (VLTI) now being built in Chile and NASA's Space Interferometry Mission (SIM), due to launch in 2009. SIM will spend five years probing nearby stars for Earth-sized planets. Present-day searches will provide target lists for SIM and the VLTI.

Is it worth finding more planets? Absolutely, says Butler. "It will be at least five years before we find enough planets to even begin making sensible guesses about the whole population out there."

But the planets found to date are so different from those in the solar system that theories of planet formation have been "turned on their head," he said.



Search for Another Earth Quietly Underway

By Robert Roy Britt, Senior Science Writer
posted: 07:00 am ET, 30 November 2000

After a five-year search that has turned up more than 40 giant, inhospitable planets around other stars, the hunt is quietly underway to discover another place like home. And while no scientist can say for sure that any such planet exists, optimism is high that another Earth will be found within the decade, possibly much sooner.

It would be a discovery of sizeable historic proportion, akin to learning that our solar system was not the center of the universe and recharging the growing expectation that we are not alone.

And it could galvanize and accelerate efforts to explore space to a degree not seen since the U.S.-Soviet space race.

The sheer volume and variety of extrasolar planets found so far fuels a strong expectation among those involved in the search that there must be other Earth-sized planets orbiting other stars at distances suitable for supporting life.

"There are about 200 billion stars in our galaxy," said Paul Butler of the Carnegie Institution of Washington. "I would guess that Earth-like planets must exist."

Butler and a colleague, Geoffrey Marcy, pioneered the hunt for extrasolar planets, or exoplanets. They lead teams that detect small wobbles in stars caused by the gravitational pull of an orbiting planet. Along with their colleagues, they have found the majority of confirmed other worlds.

But the wobble method so far spots mostly very large planets that orbit extremely close to their host stars -- many are closer than Mercury is to our Sun -- not a place you'd want to live. And scientists have yet to see these planets directly.

Now, new methods and a handful of missions on the horizon are close to bringing another Earth within our optical reach.

Earth-sized planet discovery imminent

In recent interviews, three leading planet hunters told SPACE.com that a potentially habitable Earth-like planet might well be found within 10 years. And extrasolar planets in the "terrestrial" range -- no more than 2.5 times the size of Earth -- could be found within five years, possibly even during 2001.

Discovering one of these so-called "terrestrials" could well spur the funding, decisions and brainstorming needed to support missions that would root out truly habitable planets, scientists say.

Hans J. Deeg, a planet hunter involved in multiple searches, says if either of two planned missions gets off the drawing boards in a timely manner -- the ESA's Eddington mission or NASA's Kepler mission -- then a truly Earth-sized planet should be found in about 10 years.

Meanwhile, Deeg is currently working on COROT, a European space-based telescope due to launch in 2004.

Future Missions to Search for Earth-like Planets

By Robert Roy Britt, Senior Science Writer
posted: 07:00 am ET, 30 November 2000

Several space missions have been dreamed up to search for Earth-like planets around other stars. Some may remain dreams, others are closer to reality. Here, we detail six of the more promising candidates (though there are many others).

COROT mission

The French space agency CNES leads a group that is designing COROT (COnvection, ROtation and Transits). This small Earth-orbiting telescope will likely be the first space telescope dedicated to the search for Earth-like planets. Most other planet hunting so far has been done with ground telescopes or, when space telescopes have been use, time has been limited.

COROT would detect planets when they happen to pass in front of their host star, an event known as a transit, which causes a dip in the brightness of the star.

The telescope is only 27

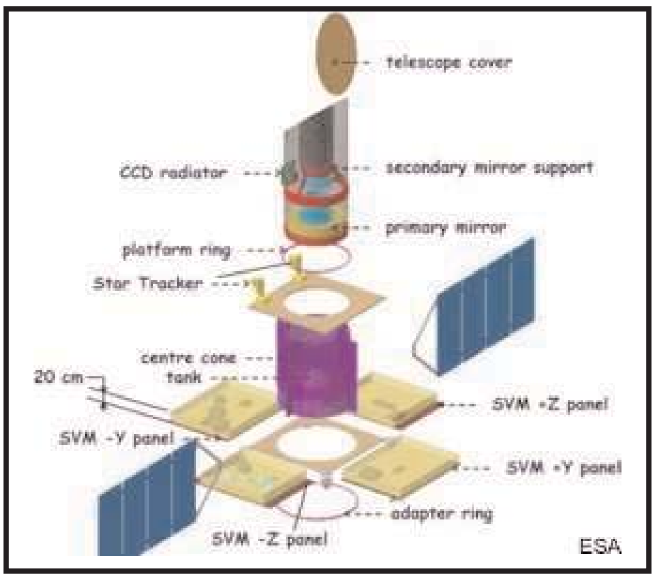
centimeters (10.6 inches) in diameter. Its value would lie in the fact that it would sit above the blurring effects of Earth's atmosphere and that it would be devoted to the task of exoplanet hunting. Some stars will be studied for five months, to build strong signals that can then be picked out.

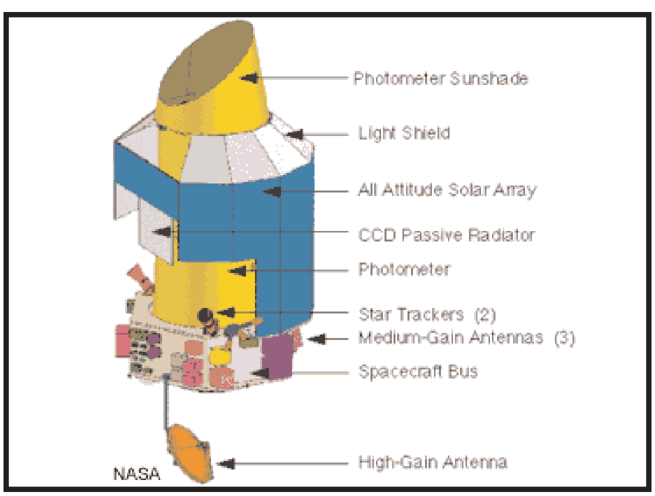
COROT participants include Spain, Austria, Belgium, ESTEC, Italy and the European Space Agency (ESA). Promoters say it will launch in 2004.

Eddington mission

The Eddington mission was proposed to the European Space Agency (ESA) in early 2000. It would search for and study potentially habitable planets around other stars using a 1.2-meter (47-inch) optical telescope.

Eddington would carry an optical photometer mounted on a three-axis stabilized platform, sitting far from Earth. The mission would also study the makeup and evolution of stars.





In October, the ESA's Science Program Committee approved Eddington as part of a larger set of initiatives to be implemented between 2008 and 2013. A workshop to discuss the mission will be held June 11-15, 2001, in Spain.

Kepler mission

The Kepler mission has been proposed as an element in NASA's Discovery Program. Its goal would be to survey relatively nearby stars to detect and characterize hundreds of terrestrial and larger planets -- if they exist -- in or near the habitable zone.

The satellite's telescope would have a 0.95-meter (37-inch) aperture. It would orbit the Sun and study some 100,000 stars for four years.

Kepler would study the size, orbit and composition of any Earth-like planets it found, and would also study the properties of stars that harbor planetary systems. The mission could get approval in December of this year, or possibly January 2001. No launch date has been projected.

Darwin mission

The European Space Agency has targeted the InfraRed Space Interferometer-Darwin for a launch in 2015 or later. Decisions about whether to go forward with the mission are expected around 2003.

The telescope, using infrared rather than optical wavelengths, would hunt for Earth-like planets around some 300 Sun-like stars within 50 light-years of Earth. Darwin would actually be an array of six small eyes, forming an effective giant that would mimic a 100-yard (91-meter) telescope. Scientists are still studying how such a system might be designed.

Unlike current space-based telescopes, Darwin would operate somewhere between Mars and Jupiter, rather than in Earth orbit. This would allow the instruments to avoid the dust between Earth and Mars that obscures the view.

The six individual telescopes would be joined either by long arms or would each be mounted on individual spacecraft. In the former case, the rigid structure would rotate to build up the image. In the latter case, the individual spacecraft would have

ALCATEL SPACE

their own rocket motors and dance around each other to build up the image.

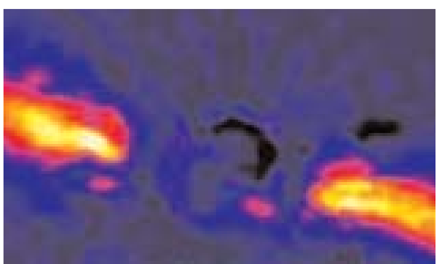
SIM mission

The Space Interferometry Mission (SIM) would hunt for Earth-sized planets around other stars and provide new insights into the origin and evolution of our galaxy.

A science team for the mission was chosen by NASA November 28, 2000, and the mission is scheduled for launch in 2009.

SIM would be placed into orbit around the Sun on a path that follows Earth's orbit. Light gathered by its multiple telescopes will be combined and processed to yield information that could normally be obtained only with a much larger telescope.

The mission would also measure the locations and distances of stars throughout our Milky Way Galaxy, and study other celestial objects.



CREDIT: ESO/CALTECH

Solar Systems Like Ours May Be Common, Study Shows

By Robert Roy Britt, Senior Science Writer
posted: 07:02 am ET, 04 January 2001

Researchers have discovered unexpected amounts of hydrogen gas, critical to the formation of giant planets like Jupiter, circling three nearby stars in dust disks previously thought to be devoid of the stuff.

While hydrogen is the most common substance inside stars and throughout the universe, the finding indicates that hydrogen remains in a dust disk, or protoplanetary disk, around a star longer than thought. This, in turn, means large gas planets have longer to form and therefore may be more prevalent than expected.

Coupled with the long-held theories that gas giants are necessary for the formation of smaller Earth-like planets, the discovery raises intriguing possibilities about the search for other planets that might harbor life.

"The new findings strengthen the likelihood that a larger fraction of stars form solar systems like our own, and that some stars near the Sun are still forming giant planets," said Jack Lissauer, a researcher at NASA's Ames Research Center who was not involved in the study.

Enough hydrogen for six Jupiters

The three stars in the study are relatively young -- between 8 million and 30 million years old (our Sun formed nearly 5 billion years ago). Each is less than 260 light-years away (our Milky Way Galaxy is roughly 100,000 light-years across).

Each of the stars was known to be encircled by a flat disk of dust. These so-called protoplanetary disks, the leftovers of star birth, are the stuff of which planets are made. But previous studies had concluded the disks contained very little hydrogen gas. Researchers assumed that hydrogen does not hang around in a dust disk for more than about 5 million years. (The interplanetary space in our own solar system is now mostly hydrogen-free.)

The new study, reported in the Jan. 4 issue of the journal Nature, found enough hydrogen gas around one of the stars to form six Jupiters. Each of the other two disks had a fraction of the hydrogen needed to make one Jupiter, but still more than expected.

Many of the stars in our neighborhood of the Milky Way are at least 10 million to 30 million years old. Until now, researchers assumed these stars could no longer form giant planets, because their disks would be depleted of hydrogen gas.

According to theories of solar system formation, giant planets are key to allowing the development of smaller planets in potentially habitable orbits -- not too hot, not too cold. Gas giants, as the theory goes, also help set up livable conditions as they use their gravity to sweep the inner solar system relatively free of life-threatening asteroids and comets.

The researchers involved with the study said their work is "good news, though indirectly, in the search for extraterrestrial life," because life as we know it needs a planet in one of these so-called "Goldilocks" orbits. Clues to our own solar system.

The findings also represent another step toward fathoming the range of ways in which solar systems, including our own, come into being and evolve.

"If indeed planet formation is still going on in these [nearby] systems, they are among the closest to the Earth," said Geoffrey Blake, a Caltech researcher who participated in the study. "They may therefore provide unique windows into how planetary systems are assembled."

Classic explanations of giant-planet formation say that a core of rock roughly 10 times the mass of Earth forms, and then the gravity of this "protoplanet" attracts gas until it becomes the size of Jupiter. But computer models have shown this would take several million years -- longer than hydrogen gas was expected to be available.

"Our new findings are important because they lengthen the time that it is possible to form Jupiter-like planets," Blake told SPACE.com.

Telescope Array to Unlock Secrets from Duplicitous Stars

By Robert Roy Britt, Senior Science Writer
posted: 07:00 am ET, 17 July 2001

MOUNT WILSON, CALIF -- A steep and narrow road shouldered by precipitous drops into rocky canyons winds from the bright lights of the Los Angeles Basin to the top of Mount Wilson. It's an hours drive that soars up through the smog, past sturdy pine trees and, surprisingly, into some of the best telescopic "seeing" conditions in the world. It is also a paved path to the past. Some of the equipment here has sat unchanged since the 1920s when Edwin Hubble used the mountain's 100-inch telescope to discover that our universe is expanding.

Now, eight decades after Hubble ushered in a new era of cosmology, and on the heels of a complete shutdown, the Mount Wilson Observatory is alive again and being repositioned for the future by going back to basics. It is a future expected to unlock fundamental secrets about ordinary stars, objects that have lost some of their "star power" in an era of pretty pictures made by exotic space-based telescopes. Like the one named after Edwin Hubble.

Under the steady air at Mount Wilson, scientists are building an array of telescopes that will combine to work as one and effectively become among the most powerful stargazing tools ever built.

The setup is so complicated that no one person understands how it works. It is called the CHARA array, and later this month scientists plan to start normal operations as they bring the third telescope in the complex array online. The longest distance between two of the telescopes, known as the array's baseline, will be 1,148 feet (350 meters), nearly the length of four football fields. By comparison, the largest conventional optical telescopes do not exceed 36 feet (11 meters).

CHARA is expected therefore to allow astronomers to measure and weigh stars and calculate distances to them with a precision not previously possible.

Out of the age of occultations

Other telescopes -- including Hubble, Chandra, Hawaii's Keck and the European Southern Observatory's Very Large Telescope -- are better equipped to look beyond our Milky Way to explore distant galaxies or to marvel at supernovae, exoplanets and other enigmatic objects. If those are an astronomer's most elegant power tools, then CHARA could be considered a supercharged slide rule.

And unlike a handful of similar telescopes that perform diverse tasks, CHARA will be dedicated to the basic measurement of stars in visible and near-infrared light. Such measurements have until now relied heavily on lunar occultations, a moderately reliable method of studying how a star's light goes out during the seconds when the Moon chances to pass in front of it.

CHARA (Center for High Angular Resolution Astronomy) is expected to give significantly improved measurements of the mass of stars, a crucial factor in learning what the objects are made of and how they evolve.

Other research has indirectly measured the mass of stars by observing how two stars orbit around one another in what's called a binary system. But these observations have relied on noting changes in the star's light as it moves away from us, and then toward us, in its orbit.

This Doppler effect, identical to the change in sound as an ambulance moves toward and then away from you, is an indirect measurement tool that, again, has only provided reasonably close estimates.

What CHARA's interferometry can do that the Doppler method and conventional telescopes can't is to actually locate points around the perimeter of a star, thus providing an exact "picture" of a star's diameter. Other methods use a star's luminosity to estimate other parameters.

"If you can resolve these binary stars ... then you can directly measure the masses of the two stars as well as the distance to the stars from Earth," says Harold A. McAlister, a Georgia State University professor and director of the 14-person CHARA team. "The measure of mass is the most fundamental parameter scientists would like to know" about stars.

Duplicitous by nature

Stars are often duplicitous by nature, doubling up just to confuse observers and even, at least in the past, being perceived as evil. CHARA will help untangle stars' deceptive properties.

Roughly half of all the points of light in the night sky are actually binary star systems, in which two stars orbit around a common gravitational midpoint. Such systems give off confusing light signatures that in some cases move in the sky, sometimes sending airliners off course and generally confounding attempts to measure their size, distance, substance and movement.

One such binary system was once thought to be a single star. Its frequent winking gave the ancients the creeps, and so they gave the strange object the name Algol, meaning Eye of the Demon.

Algol, modern-day astronomers learned, has a small faint companion star that orbits around it, explains Bill Hartkopf of the U.S. Naval Observatory. Every few days the smaller star passes in front of the big star, making the system dimmer.

Hartkopf is interested in using CHARA to learn more about star systems like Algol, as well others that appear to actually move around in the sky. "Consider a star sitting out there in space all by itself, a perfect directional beacon for a jet to use to plot its course," Hartkopf said. "Unbeknownst to the pilot, however, the star slowly, imperceptibly moves -- and not even in a straight line -- enough to throw the jet off course." The moving beacon, Hartkopf explains, is a bright star accompanied by a faint star. "They're too close together to be seen as two stars," he said. "Instead we see the blended light from both. As the brighter star moves from, say, left of the fainter star to above it, then to the right of it, the center of light of that blended image appears to move in a circle."

Hartkopf says CHARA may help answer other important questions:

- Do binaries stay together forever?
- What role does a binary system play in stellar evolution?
- Do all stars form in pairs?

Recent evidence has shown that current estimates of binary systems may be incomplete. Or some stars may form in pairs and later be forced apart.

No one person understands it

The technique of combining light from multiple telescopes is called interferometry. Radio telescopes have employed it for years, but it is just emerging as a force in optical astronomy. It's all about making a big deal of small things. "When you want to see a small thing in the sky, you need a big mirror," says Mark Swain, an astronomer and technician at NASA's Jet Propulsion Laboratory who works on the Keck telescope. Keck is also an interferometer but is devoted to hunting for extrasolar planets.

"Interferometers are a cheap way to build a big mirror," he says. "A mirror the size of a football field would be tremendously expensive, if even possible." CHARA's original budget forecast put the project at $11.5 million -- a fraction of what it costs to build and launch a space-based telescope. But with the relatively cheap price tag comes a complex method of putting the light back together. Interferometry is a rapidly developing technique that requires nanometer precision. And it is a scheme that is highly complicated. So much so that nobody claims to be able to boil it down to anything resembling a lay explanation.

"No one person understands it all," says Lu Rarogiewicz, who worked on a predecessor to CHARA that was dismantled three years ago. "It takes a team of fairly specialized people in many disciplines to put it together and get it to work." McAlister, while giving a quick overview to a group of journalists visiting the observatory, called the technique a "magical process" that "involves a lot of plumbing." The magic is in the mixing.

Imagine starlight coming from a point at the left edge of a star's disk. The light will travel a slightly longer path to reach one of two telescopes. The trick in interferometry is getting those two incoming light sources to meet at one location with near-perfect precision -- to well within the length of a single light wave.

McAlister and his colleagues do this by sending the light through vacuum tubes to a central building, a long, cramped bunker where the magic mixing is done. Inside, each beam of light is bounced between mirrors and delayed as needed until they are all exactly cued up to be combined.

As the light waves are put together, they interact and produce a series of wave patterns, called fringes, that are either built up or canceled out depending on the telescope's baseline.

Instead of conventional pictures, an interferometer produces multiple fringes, mere squiggles on a computer screen, that can be combined to determine a star's size and shape. But these can be powerful squiggles.

CHARA's ability will be akin to looking from New York, across America and the Pacific Ocean, and spotting a nickel in the middle of Siberia. In astronomy-speak, that's 200 micro-arcseconds of resolution.

The array will eventually consist of six telescopes, each with a light-collecting mirror that is 1 meter in diameter (3 feet). Since 1999, two of the telescopes have been working, but useful observations require a third, which is expected to come online later this month. All six should be operational by early next year, refining accuracy and allowing for quicker observations.

Clear skies above, crud below

On a clear, shirtsleeve-warm evening in early June this year, a full Moon outshines most stars, even high atop Mount Wilson. But those that remain exhibit a characteristic prized by astronomers: They don't twinkle.

Which is precisely why the site was chosen for the CHARA array, even though it is less than 20 miles from the bright lights and heavy smog of downtown Los Angeles. It's the same reason the mountain got its first telescope in 1889.

"The prevailing winds bring in air that has been flowing across the Pacific Ocean and, except during storms, the temperature is very steady and the air becomes very uniform and flows very smoothly," McAlister explains.

"The air is not disrupted until it flows inland from Mount Wilson," he said. "When you observe stars from a sight like this, the stars don't twinkle much. The twinkling is the result of turbulent air distorting starlight."

The smooth flow of air also traps industrial and auto emissions in an inversion layer, creating the smog that snuggles against the mountains like dirty cotton.

Mount Wilson's elevation is just over 5,700 feet (1,742 meters). "And the inversion layer is typically at 3,000 to 4,000 feet," McAlister said. "So all the crud is down there."

Expect surprises

In addition to binary stars, CHARA will study some of the most massive stars, hot young objects known as O- and B-type stars. It will also take a look at some lower-mass, cooler stars that have proved particularly difficult to study by other means.

What's known about all these stars is based heavily on theory, not on observation, McAlister said. "These stars blow away a lot of their mass," he said. "They have very active winds of material that they expel out into the environment around them. And so we expect to see features of those winds as well."

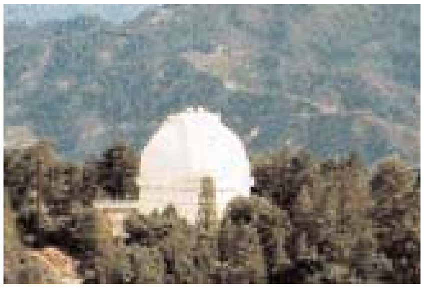
The CHARA array "should be a very good system, and it should tell us a great deal about the newer stars," said Nobel laureate Charles Townes, who operates a similar but portable interferometer, also atop Mount Wilson, and recently used it to learn that some older stars, called red giants, may be larger than thought.

McAlister said he figures that just like Townes' study of older stars, CHARA's fresh look at younger stars will yield surprises.

To a lesser extent, the array will also look for Jupiter-mass planets in binary star systems, something that is mostly ignored by current planet hunters, who typically confine their studies to single stars.

"Most of the stars in the universe are not singles, so we shouldn't be ruling out binaries ... as places for planets," McAlister said.

CHARA is funded by the National Science Foundation, the W.M. Keck Foundation, the David and Lucile Packard Foundation, and Georgia State University, which will operate it.



Astronomy Revival: New Discoveries from Historic Mount Wilson

By SPACE.com Staff, posted: 10:31 am ET, 12 June 2002

On the California mountain from which Edwin Hubble discovered that the universe was expanding, astronomers have achieved first light with a new infrared camera and made some nifty discoveries in the process.

Using the 100-inch telescope at the Mount Wilson Observatory near Pasadena, the astronomers found three previously undetected faint stars, each orbiting larger and brighter companion stars.

"This is the first time the historic Mount Wilson telescope has looked at the universe through this new infrared eye, and already it is making new discoveries," said Jian Ge, assistant professor of astronomy and astrophysics at Penn State and leader of team that developed the camera and made the discoveries.

The results do not represent a major scientific finding -- similar dim stars have been discovered from other observatories. But they "mark the beginning of a new era in the use of the 100-inch telescope for discovering very interesting faint objects in orbit around brighter stars, such as brown dwarfs, which are neither stars nor planets," said Robert Jastrow, director of the Mount Wilson Institute.

The findings will be published in the June issue of Astrophysical Journal Letters and the July issue of the Astronomical Journal.

The infrared camera, which detects electromagnetic radiation in the form of heat rather than visible light, has a specially shaped mask that covers the "pupil" of the camera's eye to allow fainter companions to be seen around bright objects.

"The image resulting from the first use of the device revealed areas of greater contrast that allowed us to find one of the faint dwarf stars," Ge said. "The technique potentially improves contrast in images by more than tenfold compared to current techniques." (Other telescopes are equipped with similar coronagraphs, as they are called.)

Future space-based telescopes will likely draw from this technology to image Earth-like planets around other stars, said David Spergel, Princeton University researcher who recommended the new approach to Ge. "Jian's work at Mount Wilson is a pathfinder for the Terrestrial Planet Finder being planned by NASA."

The dwarf stars are less than one-tenth the mass of the Sun and give off a dark-red glow that is dimmer than our hotter Sun's yellow light. One of the stars is about 50 light years from Earth, another is about 27 light years away, and the third is at a distance of about 200 light years. Astronomers consider these stars to be nearby in our solar system's corner of the galaxy.

"Our initial conservative estimate is that these are little very-dark-red dwarf stars," says Abhijit Chakraborty, a postdoctoral scholar on Ge's team. "Their mass is only about 80 to 100 times that of Jupiter, which itself is a thousand times smaller than our Sun. They have barely enough mass to burn the hydrogen in their cores, and are close to the size and luminosity of less-massive brown-dwarf objects, which don't have enough mass to ignite into stars at all."

300th Delta Rocket Launches New Window on Universe

BY WILLIAM HARWOOD
STORY WRITTEN FOR CBS NEWS "SPACE PLACE" & USED WITH PERMISSION
Posted: August 25, 2003

With a sky-lighting burst of flame and thunder, a Boeing Delta 2 rocket boosted a $1.2 billion infrared telescope into space early today, a "great observatory" designed to detect the feeble glow of infant planets, stars and galaxies in the making.

In so doing, NASA's Space Infrared Telescope Facility, or SIRTF (pronounced SIR-tiff), will complement the work of the Hubble Space Telescope and the Chandra X-ray Observatory while extending humanity's vision into a realm that, until now, has been shrouded in dusty mystery.

An artist's concept of SIRTF. Credit: NASA/JPL/Caltech

"The technical capability of SIRTF will most likely lead to discoveries that no one could predict before the start of the mission," Lia La Piana, program manager at NASA headquarters in Washington, said earlier this year. "SIRTF will significantly increase our understanding of the Universe and will probably re-write astronomy textbooks just like the Hubble Space Telescope did."

Once safely in orbit around the sun, its instruments activated, checked out and chilled to a few degrees above absolute zero - a process that will take up to three months to complete - SIRTF will be the most powerful space-based infrared observatory ever built.

So sensitive, in fact, it would be capable of detecting the pulse from a TV remote control "clicker" from a distance of 10,000 miles.

"SIRTF will be a factor of a hundred to a million times more capable than any previous facility for infrared astronomy," said Michael Werner, SIRTF project scientist at the Jet Propulsion Laboratory in Pasadena, Calif. "I'm fond of saying that SIRTF doesn't just meet our requirements, it exceeds our requirements. It's going to be very, very exciting over the next months and years."

Running four-and-a-half months late because of booster issues and the launchings of two Mars rovers this summer, SIRTF's Delta 2 finally roared to life at 1:35:39 a.m. EDT (0535:39 GMT) Monday, swiftly climbing away from pad 17B at the Cape Canaveral Air Force Station.

The fiery exhaust from the vehicle's powerful Delta 3-class solid-fuel boosters lighted up the night sky for miles around, putting on a spectacular show for area night owls. Fifty minutes later, after two firings by the Delta 2's second stage motor, SIRTF was released into an orbit around the sun designed to maximize the spacecraft's science output.

Engineers were not initially able to acquire telemetry from the spacecraft as it sailed high above Australia, causing a few tense moments following SIRTF's separation from the Delta 2's second stage. But as it turned out, all was well.

"I have no nails left," joked project manager David Gallagher. "We had a little extra delay there acquiring (telemetry) from Canberra. We have done a preliminary assessment of the subsystems of the observatory and everything looks to be good. We are pointing where we should be.

"We believe, this is very preliminary, the cause of the delay was that the signal was too strong. ... We are getting telemetry down now and everything looks good."

Launch came two full decades after the project first got underway with an official "announcement of opportunity" from NASA.

"We were all foolish enough not to notice it was actually Friday, May 13," said George Rieke, a principal investigator from the University of Arizona. "Somehow we have overcome, after two decades, the bad aura that came with that particular date."

The victim of budget cuts and resulting redesigns, SIRTF survived primarily due to the innovation and determination of the science team and the engineers charged with turning the dream into reality.

"We used to count the time to SIRTF's launch in decades," Rieke joked. "If we'd known how many decades, we probably would have quit."

The key was figuring out how to reduce the weight of the telescope to permit launch on a low-cost Delta while maintaining the same mirror size, the same orbital lifetime and the same capability to chill the observatory's instruments to within five degrees of absolute zero. The solution was as elegant as it was simple.

Instead of encapsulating the telescope in a massive liquid helium dewar, or thermos, like earlier, more modest infrared telescopes, engineers decided to launch SIRTF at room temperature. Once in space, a smaller dewar holding 95 gallons of liquid helium will begin cooling the optical system and instrument detectors.

But that alone was not enough. To achieve the ultra-low temperatures required to detect the faintest targets, SIRTF was redesigned to operate in the shade of a single fixed solar panel that will always remain pointed face on to the sun.

Finally, the SIRTF designers changed the mission profile, putting the telescope in an orbit around the sun instead of Earth, far enough away to eliminate infrared emissions from the planet or the moon that otherwise could wash out the feeble radiation from deep space.

All of that, plus the addition of the largest, most sensitive digital detectors ever built for an infrared telescope, represents "a great advancement in the state of the art for infrared observatories," Gallagher said earlier this year.

SIRTF is equipped with three science instruments: A powerful CCD camera sensitive to shorter infrared wavelengths, a light-splitting spectrograph to study the chemical composition of the telescope's targets and a multi-band photometer that will gather pictures and spectrographic data at longer wavelengths.

"The only real downside to this warm-launch architecture is it hasn't been done before," Gallagher said. "So this is a first of a kind demonstration of that. I believe after it's successful, this will become the way you do infrared missions. By not having to cool such a large volume, the mass savings, and therefore cost savings, are quite extraordinary."

Slowly falling behind Earth in a slightly longer orbit around the sun, SIRTF will focus on the faint heat emitted by stars and planets in the process of coalescing from swirling clouds of dust and gas. The 1,900-pound observatory also will probe the chemical composition of enigmatic brown dwarfs, would-be suns that lack sufficient mass to trigger nuclear ignition, and peer through intervening clouds of dust to map the hidden heart of the Milky Way.

Closer to home, SIRTF's chilled 33.5-inch mirror and a trio of sensitive detectors promise to give astronomers an unprecedented view of the outer reaches of our own solar system, where uncounted comets and icy chunks of debris slowly swarm about the faint flicker of the distant sun.

Of more cosmological significance, SIRTF will peer into the depths of space and time, capturing the faint glow of the first infant galaxies emerging in the aftermath of the big bang as well as emissions from the cooler outer regions of black hole-powered quasars.

"SIRTF will allow us to probe the young Universe in ways which compliment the work that's been done to date with Hubble and with Chandra, the other great observatories," said Garth Illingworth of the University of California-Santa Cruz. "We're looking now to try and shed light on the mystery of galaxies, when they were born, how they were assembled and how they've grown over the life of the Universe."

It's a tall order. Figuring out how galaxies evolved in the aftermath of the big bang birth of the cosmos "is really and truly one of the great quests of the next decade," Illingworth said.

SIRTF is the fourth and final member of NASA's "Great Observatories" program, following the Hubble Space Telescope, the now-defunct Compton Gamma Ray Observatory and the recently launched Chandra X-ray Observatory.

The idea was to build a fleet of space-based telescopes sensitive to different regions of the electromagnetic spectrum because "many cosmic objects produce radiation over a wide range of wavelengths," said NASA science chief Ed Weiler. "It's important to get the whole picture."

The Compton Gamma Ray Observatory, which ended its mission in 2000, was built to study extremely violent processes, catastrophic stellar detonations and collisions generating temperatures greater than 1.8 billion degrees Fahrenheit.

Chandra studies slightly less powerful million-degree X-ray processes like the enormous heating of gas and dust sucked into ravenous black holes. The Hubble Space Telescope is primarily a visible-light instrument, sensitive to the radiation emitted by stars, galaxies and interactions that generate temperatures measured in the thousands of degrees.

SIRTF is optimized to capture infrared emissions from objects and processes that generate temperatures of a few hundred degrees or less.

Barriers to Space: And Why They Should Be Overcome

By Douglas Vakoch, Special to SPACE.com
posted: 07:00 am ET,11 September 2003

"It's extremely difficult to live and work in space," says psychologist Albert Harrison, who compares a stint onboard the International Space Station to "being in a cramped house with trash piling up." While the wobbly legs of an astronaut just returned to Earth may be the most obvious side-effect of a year-long space mission, simply getting along with other astronauts for months at a time may be even harder.

According to Harrison, author of Spacefaring: The Human Dimension, "One of the things that the Russians have done with tremendous skill and daring is to build a record of increasingly long space flights. Our own astronauts gained experience on Skylab and later on Mir and the ISS." As a result, "the people that go up into space have been able to get along with one another. They work out patterns of mutual existence, living under conditions where they're cramped together." In orbit 240 miles above the Earth's surface, astronauts who tire of being in close quarters have "very little opportunity to get away."

And in their celestial home away from home, there's little room for solitude. Long gone are the days of the Mercury space capsules, with room for only one astronaut on missions measured in hours. But like their predecessors, Harrison says, today's "astronauts still have the 'Right Stuff,' it's just that it's redefined a little bit."

"The 'Right Stuff' has sort of expanded," in Harrison's view. Modern astronauts are "still highly competent and motivated and they're still cool. Today they don't have to be fighter pilots with great kill ratios ... but they do have to be able to get along with one another in ways that weren't required in the 1960s." The challenges of long-term amity can become even more difficult when astronauts come from cultures with different ways of relating to others. "Today's international crews," says Harrison, "raise the complexity. A lot of effort goes into ensuring that international crews can function comfortably."

The Greatest Obstacle

But interpersonal strife is far from the worst threat to a stable space program. Commenting on the space program in the United States, Harrison says if he had "to pick one problem which is greater than others, I think it's national will, our desire to go to space, to provide the political infrastructure and the economic support to realize that dream."

Harrison identifies three critical ingredients to a successful space program: technology, money, and commitment. "We do have the technology, and if we choose to spend it, we do have the money." But in recent years, he says, America hasn't maintained a commitment to a strong presence in space.

Though the Russians and the Chinese may have fewer resources, Harrison could well imagine either country soon surpassing the United States in space. "The Russians are a little short on cash, the Chinese are a little short on technology, but they both seem to be very determined, and it's quite possible that one day within the next five years or so-somewhere around 2007, 2008 we will see a Russian space station with tourists and a Chinese manufacturing facility."

Risky Business

"We're all happy to see the smiling faces and occasional clowning around of astronauts, on the shuttle or in the space station," Harrison says, but he warns, "We should never lose sight of exactly how dangerous and how demanding and how exacting space travel is."

Six months ago, the world was reminded of these dangers when the Columbia space shuttle exploded. Such risks, Harrison says, can never be eliminated completely. "The reality is that whenever we go where people have not gone before, wherever we try something new, there's a certain level of risk. No, we don't want people to die, they don't want to die, we do everything we can to keep them alive, they do everything they can to stay alive, but it is a cost of doing this kind of business."

Harrison was particularly struck by the unanimity of those closest to the Columbia astronauts in calling for continued exploration. "The families of the astronauts that died, the other astronauts, NASA officials, the greater Johnson space community, the greater NASA community, all came forward and said, 'This is very terrible, it's very sad, but we want space exploration to continue. This is what they would have wanted.'"

Worth the Cost

In light of all these risks, is space exploration really worth it? For some, the appeal of space is economic, though Harrison advises any potential investors to take a very long-term view. While manufacturing opportunities in zero-gravity or asteroid mining may some day be a paying proposition, Harrison warns that "it's a long way from where we are now until you start getting interest on the money that you put into this."

Harrison also emphasizes the knowledge that can be gained through space faring: "We make tremendous advances in science as a result of our exploration of space." While much of this knowledge is about outer space, some has a deeper, inner significance. After looking down on our planet from orbit, where political boundaries aren't evident, some astronauts have reported a deeper understanding of the interconnectedness of all life on Earth. As Harrison summarizes their experience, "It's one planet, one people."

Though a more holistic view of Earth may help us survive as a species, Harrison suggests it may not be enough. Instead, he says that space travel might help us insure that humankind will continue to exist, even in the face of widespread disaster on our home world: "As soon as we're able to become a two planet species, as soon as we're not limited to Planet Earth, we can protect ourselves, or we can at least protect the human future, from any global level catastrophe or extinction level event."

In spite of the obstacles to space travel, Harrison remains optimistic: "I see a long, tough road, to tell you the truth, but I think that we'll eventually get there ... that we'll get back to the Moon, we'll get to Mars."

"If we don't run out of money, if we don't lose the practical know-how that we've built up, I think that our eventual movement into space is inevitable."

Quick Bites

The Galileo spacecraft will end its mission September 21, 2003 with a planned impact into Jupiter. Launched in 1989, Galileo has been exploring Jupiter and its moons since December 1995.

NASA announced the selection of the "Phoenix" mission for launch in 2007 as what is hoped will be the first in a new line of "Scout" missions in the agency's Mars Exploration Program. Press Release from the Jet Propulsion Lab. [August 4, 2003.]

New count on planetary moons . . .

- Jupiter --- forty and counting . . . . . newest names: Autonoe, Thyone, Hermippe, Aitne, Euerydome, Euanthe, Erporie,Orthosie, Sponde, Kale, Pasithee. Two moons have not yet been named.

- Saturn --- thirty and counting . . . . . newest names: Ymir, Paaliaq, Tarvos, Ijiraq, Suttung, Kivnig, Mundilfori, Albiorix, Skadi, Erriapo, Siarnaq, Thrym

- Uranus --- twenty-one and counting . . . . . newest name: Trinculo

- Neptune --- eleven and counting . . . . . . The three newest moons have not yet been named.